CLAIMS

1. A method of forming a microtube device, said method comprising:

forming a complex overwrapped mandrel on a precision-controlled adjustable-torque micro-winding device, said complex overwrapped mandrel having:

a core, and

at least one overwrapping threadlike component wound on the core, said overwrapping threadlike component being placed about said core in a predetermined manner forming a complex overwrapped mandrel;

coating said complex overwrapped mandrel with at least one material to form at least a single layer thereon to form a coated complex overwrapped mandrel; and

removing said complex overwrapped mandrel from w/in said coated complex overwrapped mandrel with a predetermined process to leave said coating forming said microtube device.

2. A method of forming a microtube device as defined in claim 1 in which the core consists of at least one microscopic object with a high aspect ratio of length to diameter or at least one fiber with a cross-sectional dimension in the range of about 1 to 1000 microns.

3. A method of forming a microtube device as defined in claim 1 in which the threadlike component consists of at least one microscopic object with high aspect ratio or at least one fiber with a cross-sectional dimension in the range of about 1 to 1000 microns.

4. A method of forming a microtube device as defined in claim 1 further including overwrapping at least one threadlike component on top of the coated complex overwrapped mandrel.

5. A method of forming a microtube device as defined in claim 4 including adding at least one additional coating on top of the at least one threadlike component overwrapping the coated complex overwrapped mandrel.

6. A method of forming a microtube device as defined in claim 5 further including removing at least one threadlike component from its coating after it has been overwrapped on top of the coated complex overwrapped mandrel.

7. A method of forming a microtube device as defined in claim 1 wherein said at least one overwrapping fiber is made of a material such as polyetherimide.

8. A method of forming a microtube device as defined in claim 1 in which the surface of said at least one overwrapping threadlike component is melted just before being wrapped on said core in order to form a melt-bond with the core.

9. A method of forming a microtube device as defined in claim 1 in which the overwrapping threadlike component is comprised of at least one previously fabricated component from the group consisting of complex mandrel, coated complex mandrel, or coated complex mandrel from

which the core, or mandrel and/or at least one coating has been removed; said previously fabricated component having been fabricated by a process selected from the group consisting of overwrapping a core, changing the radial dimensions of the mandrel, adding material to a fiber core, removing material from a fiber core, moving material on a fiber core, or a combination of these processes.

10. A method of forming a microtube with a complex wall, said method comprising:

forming a core,

placing at least one coating on said core,

forming a complex overwrapped mandrel on a micro-winding device, said complex overwrapped mandrel having a coated core, said complex overwrapped mandrel having at least one overwrapping threadlike component about said core, said overwrapping threadlike component being placed about said core in a predetermined manner forming a complex overwrapped mandrel;

coating said complex overwrapped mandrel with at least one layer of material; and

removing said core to produce a microtube with a complex wall.

11. A method of forming a microtube device as defined in claim 10 in which the core consists of at least one microscopic object with a high aspect ratio of length to diameter or at least one fiber with a cross-sectional dimension in the range of about 1 to 1000 microns.

12. A method of forming a microtube device as defined in claim 10 in which the threadlike component consists of at least one microscopic object with high aspect ratio or at least one fiber with a cross-sectional dimension in the range of about 1 to 1000 microns.

13. A method of forming a microtube device as defined in claim 10 further including depositing at least one coating on said at least one overwrapping threadlike component before overwrapping said at least one overwrapping threadlike component on the said coated core.

14. A method of forming a microtube device as defined in claim 10 further including the removal of the said at least one overwrapping threadlike component from its coating.

15. A method of forming a microtube device as defined in claim 10 further including overwrapping at least one threadlike component on top of the coated complex overwrapped mandrel.

16. A method of forming a microtube device as defined in claim 15 including adding at least one additional coating on top of the at least one threadlike component overwrapping the coated complex overwrapped mandrel.

17. A method of forming a microtube device as defined in claim 16 further including removing at least one threadlike component from its coating after it has been overwrapped on top of the coated complex overwrapped mandrel.

18. A method of forming a microtube device as defined in claim 10 wherein said at least one overwrapping fiber is made of a material such as polyetherimide.

19. A method of forming a microtube device as defined in claim 10 in which the surface of said at least one overwrapping threadlike component is melted just before being wrapped on said coated core in order to form a melt-bond with the coated core.

20. A method of forming a microtube device as defined in claim 10 in which the overwrapping threadlike component is comprised of at least one previously fabricated component from the group consisting of complex mandrel, coated complex mandrel, or coated complex mandrel from which the core/or complex mandrel and/or at least one coating has been removed; said previously fabricated component having been fabricated by a process selected from the group consisting of overwrapping a core, changing the radial dimensions of the mandrel, adding material to a fiber core, removing material from a fiber core, moving material on a fiber core, or a combination of these processes.

21. A method of forming a micro-coil threadlike component, said method comprising:

forming a complex overwrapped mandrel on a micro-winding device, said complex overwrapped mandrel having a core, said complex overwrapped mandrel having at least one overwrapping threadlike component about said core, said overwrapping threadlike component

being placed about said core in a predetermined manner forming a complex overwrapped mandrel; and

removing said core from said at least one overwrapping threadlike component to produce at least one free-standing micro-coiled threadlike component.

22. A method of forming a micro-coiled threadlike component as defined in claim 21 in which the core consists of a microscopic object with high aspect ratio or at least one fiber with a cross-sectional dimension in the range of about 1 to 1000 microns.

23. A method of forming a micro-coiled threadlike component as defined in claim 21 in which the overwrapping threadlike component consists of at least one microscopic object with high aspect ratio or at least one fiber with a cross-sectional dimension in the range of 1-1000 microns.

24. A method of forming a micro-coiled threadlike component as defined in claim 21 in which the overwrapping threadlike component has at least one coating on it before it is wrapped around the core.

25. A method of forming a micro-coiled threadlike component as defined in claim 21 in which said at least one free-standing micro-coiled threadlike component is coated with at least one layer of material to form at least one coated free-standing micro-coiled threadlike component.

26. A method of forming a micro-coiled threadlike component as defined in claim 21 further including removing said threadlike component from said coated free-standing micro-coiled threadlike component to produce a coiled microtube device.

27. A method of forming as defined in claim 21 wherein said overwrapping threadlike component is made of a material such as polyetherimide.

28. A method of forming a microtube device, said method comprising:

forming a complex augmented mandrel on a multi-axis fabrication device capable of micron or sub-micron positioning, said complex augmented mandrel having a core of at least one fiber, said fiber core having at least one type of material with a pre-determined cross-sectional shape placed on it in a continuous or non-continuous manner in at least one pre-determined location on the periphery of the core;

coating said complex augmented mandrel with at least one material to form at least a single layer thereon, producing a coated complex augmented mandrel; and

removing said complex augmented mandrel from said coating with a predetermined process to leave said coating forming said microtube device.

29. A method of forming a microtube device as defined in claim 28 wherein said material is placed on said fiber core by a liquid phase process.

30. A method of forming a microtube device as defined in claim 29 wherein said liquid phase process consists of melt extruding liquid material through a microscopic orifice or tube on to the surface of the fiber core where the liquid cools and solidifies.

31. A method of forming a microtube device as defined in claim 29 wherein said liquid phase process consists of using a microscopic orifice or tube to place a viscous liquid material on the surface of the fiber core at a minimum of one pre-determined location where it solidifies by a process such as evaporation, curing, polymerizing, or cross-linking.

32. A method of forming a microtube device as defined in claim 28 wherein said material is placed on said fiber core by a vapor phase process.

33. A method of forming a microtube device as defined in claim 32 wherein said vapor phase process consists of spraying material onto the surface through a microscopic nozzle or tube.

34. A method of forming a microtube device as defined in claim 32 wherein said vapor phase process further includes use a mask for selectively depositing material onto the surface

35. A method of forming a microtube device, said method comprising:

forming a core consisting of at least one fiber;

placing said fiber core of at least one fiber in a multi-axis fabrication device capable of micron or sub-micron positioning;

removing material selectively from said fiber core surface in a continuous or non-continuous manner in at least one pre-determined position on the periphery of the core to a predetermined depth in order to produce a complex reduced mandrel;

coating said complex reduced mandrel with at least one material to form at least one layer thereon yielding a coated complex reduced mandrel; and

removing said complex reduced mandrel from said coating with a predetermined process to leave said coating forming said microtube device.

36. A method of forming a microtube device as defined in claim 35 in which the at least one core fiber has a cross-sectional dimension in the range of about 1 to 1000 microns.

37. A method of forming a microtube device as defined in claim 35 further including removing material from said fiber core using a non-contact technique, such as a micro-heatgun, a focused beam of micron or sub-micron-sized particulate, or a focused beam of energetic particles, ions or laser radiation.

38. A method of forming a microtube device as defined in claim 37 further including removing material from said fiber core using a non-contact technique such as placing a mask between the fiber core and the heat-gun, particulate source, or source of energetic particles, ions, or laser radiation that may be focused or unfocused.

39. A method of forming a microtube device as defined in claim 35 further including removing material from said fiber core using a contact technique, such as a hot wire or filament.

40. A method of forming a microtube device as defined in claim 35 further including depositing a coating on said at least one fiber of said fiber core before removing material.

41. A method of forming a microtube device as defined in claim 40 in which the coating is a photoresist which is exposed at desired locations on the core either through a mask or directly by a focused beam of energetic particles or radiation.

42. A method of forming a microtube device as defined in claim 41 in which a portion of the photoresist is selectively removed to a desired depth at pre-determined locations on the fiber core periphery by solvation or by plasma.

43. A method of forming a microtube device, said method comprising:

forming a core consisting of at least one fiber;

placing said fiber core of at least one fiber in a multi-axis fabrication device capable of positioning on the micron or sub-micron scale;

moving material on said fiber core surface in a continuous or non-continuous manner at a minimum of one pre-determined position on the periphery of the core to a predetermined depth in order to produce a complex redistributed mandrel;

coating said complex redistributed mandrel with at least one material to form at least one layer thereon, yielding a coated complex redistributed mandrel; and

removing said complex redistributed mandrel from said coating with a predetermined process to leave said coating forming said microtube device.

44. A method of forming a microtube device as defined in claim 43 in which the at least one core fiber has a cross-sectional dimension in the range of about 1 to 1000 microns.

45. A method of forming a microtube device as defined in claim 43 in which the material is moved on said fiber core surface using techniques such as embossing or crimping.

46. A method of forming a microtube device as defined in claim 43 in which the material is moved on said fiber core surface using a hot wire or a heat source in combination with a tool.

47. A method of forming a microtube device, said method comprising:

forming a core

forming a complex variable radius mandrel from said core by causing the radial dimensions of the core to change at at least one precise location along the core axis, said complex variable radius mandrel having a uniform, non-uniform, or random variation in radius along its axis

coating said complex variable radius mandrel with at least one layer of material to form a coated complex variable radius mandrel; and

removing the complex variable radius mandrel from said coated complex variable radius mandrel forming said microtube device.

48. A method of forming a microtube device as defined in claim 47 in which the core consists of at least one fiber or at least one microscopic object with a high aspect ratio of length to diameter with a cross-sectional dimension in the range of about 1 to 1000 microns.

49. A method of forming a microtube device as defined in claim 47 in which the complex variable radius mandrel is formed by a process selected from the group consisting of extrusion, spinning, pultrusion, drawing or stretching in which at least one processing variable selected from the group consisting of temperature, pressure, spinnerette geometry, fiber tension, fiber composition, or fiber density is varied with time to produce the desired change in radius at each position along the axis.

50. A method of forming a microtube device as defined in claim 47 in which complex variable radius mandrel is formed by applying precisely positioned localized heat in conjunction with axial tension to produce a precisely-controlled decrease in radius at any desired position along the mandrel axis.

51. A method of forming a microtube device as defined in claim 47 in which the complex variable radius mandrel is formed by applying precisely positioned localized heat in conjunction

with internal pressure to produce an increase in radius at any desired position along the axis of a hollow mandrel.

52. A method of forming a micro-device, said method comprising:

selecting a core comprised of at least one previously fabricated component from the group consisting of complex mandrel, coated complex mandrel, or coated complex mandrel from which the core, or mandrel and/or at least one coating has been removed; said previously fabricated component having been fabricated by a process selected from the group consisting of overwrapping a core, changing the mandrel radial dimensions, adding material to a core, removing material from a core, redistributing material on a core, or a combination of these processes;

placing said core in a multi-axis fabrication device capable of positioning on the micron or sub-micron scale;

modifying the surface of said core in a continuous or non-continuous manner in at least one pre-determined position on the periphery of the core in order to produce a complex sequential mandrel;

coating said complex sequential mandrel with at least one material in order to form a coated complex sequential mandrel; and

removing said complex sequential mandrel with a predetermined process to leave said at least one coating forming said micro-device.

53. A method of forming a micro-device as defined in claim 52 in which the surface of the at least one previously fabricated component is modified by selectively placing material on the surface of the said at least one previously fabricated component forming a complex augmented sequential mandrel.

54. A method of forming a micro-device as defined in claim 52 in which the surface of the at least one previously fabricated component is modified by selectively winding at least one threadlike component around said at least one previously fabricated component forming a complex overwrapped sequential mandrel.

55. A method of forming a micro-device as defined in claim 52 in which the surface of the said core is modified by selectively winding at least one other previously fabricated component around said core forming a complex overwrapped sequential mandrel.

56. A method of forming a micro-device as defined in claim 52 in which the surface of the at least one previously fabricated component is modified by selectively removing material from the surface of the said at least one previously fabricated component forming a complex reduced sequential mandrel.

57. A method of forming a micro-device as defined in claim 52 in which the surface of the said at least one previously fabricated component is modified by moving or redistributing

material on the surface of the said at least one previously fabricated component forming a complex redistributed sequential mandrel.

58. A method of forming a micro-device, said method comprising:

forming a core;

coating said fiber core with at least two materials to form at least two layers thereon, yielding a coated-fiber core; and

removing one or more said coatings, either partially or completely, with a predetermined process to leave said fiber core and at least one coating forming said micro-device.

59. A method of forming a micro-device as defined in claim 58 in which the core consisting of at least one fiber or microscopic object with high aspect ratio of length to diameter is also partially or completely removed with a predetermined process.

60. A method of forming a micro-device as defined in claim 58 in which the at least one core fiber has a cross-sectional dimension in the range of about 1 to 1000 microns.

61. A method of forming a micro-device, said method comprising:

forming a core;

placing said core in a multi-axis fabrication device capable of positioning on the micron or sub-micron scale;

modifying the surface of said core in a continuous or non-continuous manner in at least one pre-determined position on the periphery of the core in order to produce a complex mandrel;

coating said complex mandrel with at least two materials in order to form at least two layers thereon, yielding a coated complex mandrel; and

removing one or more said coatings with a predetermined process to leave the complex mandrel and at least one coating forming said micro-device.

62. A method of forming a microtube device as defined in claim 61 in which the core consists of at least one microscopic object with a high aspect ratio of length to diameter or at least one fiber with a cross-sectional dimension in the range of about 1 to 1000 microns.

63. A method of forming a micro-device as defined in claim 61 in which the complex mandrel is also partially or completely removed with a predetermined process.

64. A method of forming a micro-device as defined in claim 61 in which the core is comprised of at least one previously fabricated component from the group consisting of complex mandrel, coated complex mandrel, or coated complex mandrel from which the core, or complex mandrel and/or at least one coating has been removed; said previously fabricated component having been fabricated by a process selected from the group consisting of overwrapping a core, changing the mandrel radial dimensions, adding material to a core, removing material from a core, moving material on a core, or a combination of these processes.

65. A method of forming a micro-device as defined in claim 61 in which the surface of the core is modified by selectively placing material on the surface of the core forming a complex augmented mandrel.

66. A method of forming a complex augmented mandrel as defined in claim 65 wherein said material is placed on said core by a liquid phase process.

67. A method of forming a complex augmented mandrel as defined in claim 65 wherein said material is placed on said core by a vapor phase process.

68. A method of forming a micro-device as defined in claim 61 wherein said material is placed on said core by winding at least one threadlike component around said core forming a complex overwrapped mandrel.

69. A method of forming a micro-device as defined in claim 61 in which the surface of the core is modified by selectively removing material on the surface of the core forming a complex reduced mandrel.

70. A method of forming a complex reduced mandrel as defined in claim 69 further including removing material from said core using a non-contact technique, such as a micro-heatgun, a focused beam of micron or sub-micron-sized particulate, or a focused beam of energetic particles, ions or laser radiation.

71. A method of forming a complex reduced mandrel as defined in claim 69 further including removing material from said core using a non-contact technique, such as placing a mask between the fiber core and the heat-gun, particulate source, or source of energetic particles, ions, or laser radiation that may be focused or unfocused.

72. A method of forming a complex reduced mandrel as defined in claim 69 further including removing material from said core using a contact technique, such as a hot wire or filament

73. A method of forming a complex reduced mandrel as defined in claim 69 further including depositing a coating on said at least one fiber of said core before removing material from the periphery of the core.

74. A method of forming a complex reduced mandrel as defined in claim 73 in which the coating is a photoresist which is exposed at desired locations along the core axis either through a mask or to a focused beam of energetic particles or radiation

75. A method of forming a complex reduced mandrel as defined in claim 74 in which a portion of the photoresist is selectively removed to a desired depth at pre-determined locations on the core periphery by solvation or by plasma.

76. A method of forming a micro-device as defined in claim 61 in which the surface of the core is modified by moving or redistributing material on the surface of the core forming a complex redistributed mandrel.

77. A method of forming a complex redistributed mandrel as defined in claim 76 in which the material is moved on said core surface using techniques such as embossing or crimping.

78. A method of forming a complex redistributed mandrel as defined in claim 76 in which the material is moved on said core surface using a hot wire or a heat source in combination with a tool.

79. An precision-controlled adjustable-torque micro-winding apparatus for producing mandrels for microtube devices, said winding apparatus comprising:

a pull-through vise, said pull-through vise rotating about a common axis, said pull-through vise having jaws for adjustably holding a fiber core, said fiber core being able to be pulled through said jaws of said pull-through vise;

a locking vise, said locking vise rotating about said common axis, said locking vise having jaws for fixedly holding said fiber core;

drive means, said drive means rotating said vises together, said drive means able to drive said locking vise during translation on said common axis; and

an overwrap fiber positioner located near said pull-through vise which enables the precise control of the torque on the core fiber.

80. A winding apparatus as defined in claim 79 wherein said overwrap fiber positioner has said fiber core passing therethrough, said overwrap fiber positioner having a slotted guide for holding an overwrap fiber therein while said overwrap fiber is contacting said fiber core, and including means for tensioning said overwrap fiber during application to said fiber core.

81. A winding apparatus as defined in claim 79 further including means for moving said overwrap fiber positioner about said fiber core during application.

82. A method of forming a macro-sized microtube device, said method comprising:

forming a complex overwrapped macro-mandrel on a winding device, said complex overwrapped macro-mandrel having:

a core, and

at least one overwrapping threadlike component wound on the core, said overwrapping threadlike component being placed about said core in a predetermined manner forming a complex overwrapped macro-mandrel;

coating said complex overwrapped macro-mandrel with at least one material to form at least a single layer thereon to form a coated complex overwrapped macro-mandrel; and

removing said complex overwrapped macro-mandrel from said coated complex overwrapped macro-mandrel with a predetermined process to leave said coating forming said macro-sized microtube device.

83. A method of forming a macro-sized microtube device as defined in claim 82 in which the core consists of an object with a cross-sectional dimension in the range of about 1000-25,000 microns.

84. A method of forming a macro-sized microtube device as defined in claim 82 in which the threadlike component consists of at least one microscopic object with high aspect ratio or at least one fiber with a cross-sectional dimension in the range of about 1 to 1000 microns.

85. A method of forming a macro-sized microtube device as defined in claim 82 further including overwrapping at least one threadlike component on top of the coated complex overwrapped macro-mandrel.

86. A method of forming a macro-sized microtube device as defined in claim 85 including adding at least one additional coating on top of the at least one threadlike component overwrapping the coated complex overwrapped macro-mandrel.

87. A method of forming a macro-sized microtube device as defined in claim 86 further including removing at least one threadlike component from its coating after it has been overwrapped on top of the coated complex overwrapped macro-mandrel.

88. A method of forming a microtube device as defined in claim 82 in which the surface of said at least one overwrapping threadlike component is melted just before being wrapped on said core in order to form a melt-bond with the core.

89. A method of forming a microtube device as defined in claim 82 in which the overwrapping threadlike component is comprised of at least one previously fabricated component from the group consisting of complex mandrel, coated complex mandrel, or coated complex mandrel from which the core, or mandrel and/or at least one coating has been removed; said previously fabricated component having been fabricated by a process selected from the group consisting of overwrapping a core, changing the radial dimensions, adding material to a fiber core, removing material from a fiber core, moving material on a fiber core, or a combination of these processes.

90. A method of forming a macro-coil of threadlike component, said method comprising:

forming a complex overwrapped macro-mandrel on a winding device, said complex overwrapped macro-mandrel having a core, said complex overwrapped macro-mandrel having at least one overwrapping threadlike component about said core, said overwrapping threadlike component being placed about said core in a predetermined manner forming a complex overwrapped macro-mandrel; and

removing said core from said at least one overwrapping threadlike component to produce at least one free-standing micro-coiled threadlike component;

91. A method of forming a macro-coil of threadlike component as defined in claim 90 in which the core consists of an object with a cross-sectional dimension in the range of about 1000-25,000 microns.

92. A method of forming a macro-coil of threadlike component as defined in claim 90 in which the overwrapping threadlike component consists of a microscopic object with high aspect ratio or at least one fiber with a cross-sectional dimension in the range of 1-1000 microns.

93. A method of forming a macro-coil of threadlike component as defined in claim 90 in which the overwrapping threadlike component has at least one coating on it before it is wrapped around the core.

94. A method of forming a macro-coil of threadlike component as defined in claim 90 in which said at least one free-standing macro-coil of threadlike component is coated with at least one layer of material to form at least one coated free-standing micro-coiled threadlike component.

95. A method of forming a macro-coil of threadlike component as defined in claim 90 further including removing said threadlike component from said coated free-standing macro-coiled threadlike component to produce a macro-coiled microtube device.

96. A method of forming a macro-coil of threadlike component as defined in claim 90 in which the overwrapping threadlike component is comprised of at least one previously fabricated component from the group consisting of complex mandrel, coated complex mandrel, or coated complex mandrel from which the core or mandrel and/or at least one coating has been removed; said previously fabricated component having been fabricated by a process selected from the group consisting of overwrapping a core, changing the radial dimensions, adding material to a fiber core, removing material from a fiber core, moving material on a fiber core, or a combination of these processes.

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